

'Lucia', 'Manteo', and 'Shelby' Root-knot Nematode-Resistant Cucumber Inbred Lines

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Root-knot nematodes (*Meloidogyne* spp.) are a major problem of cucumber (*Cucumis sativus* var. *sativus* L.) production in North Carolina, as well as in other southern states. In North Carolina, root-knot nematodes destroy ≈11% of the crop annually (St. Amand and Wehner, 1991). *Meloidogyne arenaria* (Neal) Chitwood and *M. javanica* (Treub) Chitwood are often associated with cucumbers in the south, but *M. incognita* (Kofoid and White) Chitwood is the primary species that infects cucumbers in the southeastern United States. Resistance to *M. arenaria* race 2 and *M. javanica* has been found in *Cucumis sativus* var. *hardwickii* (R.) Alef. line LJ 90430 (Walters et al., 1993). That breeding line also has resistance to *M. arenaria* race 1 (Walters, 1997). Although all cucumbers are resistant to *M. hapla*, it would be useful to have cultivars resistant to one or more of the other species to provide growers with disease control with reduced nematicide applications.

Elite cucumber cultivars with resistance to root knot caused by *Meloidogyne arenaria* races 1 and 2, *M. javanica* and *M. hapla* have recently been developed, and are being released as 'Lucia' (NC-46), 'Manteo' (NC-44), and 'Shelby' (NC-45).

Origin

'Lucia', 'Manteo', and 'Shelby' were developed from the improved North Carolina hardwickii 1 (NCH1) cucumber population. The development of NCH1 population was begun in the late 1970s at North Carolina State Univ., and the original population had approximately 35% LJ 90430 germplasm in its background. NCH1 was developed by intercrossing 12 cultivars, breeding lines, and plant introduction accessions with LJ 90430 (Fig. 1). The NCH1 population was selected and

intercrossed for nine cycles to improve total, marketable, and early yields, and fruit shape of plants having American pickling-type fruits.

Inbred lines were developed from half-sib families taken randomly from the NCH1 cycle

9 population, self-pollinating them, and selecting for resistance to *M. javanica* to develop S1 lines. Root-knot nematode resistance was based on gall index, rating the roots for percentage of roots galled (Barker et al., 1986). A split-root technique (Walters et al., 1995) was used to select for resistance to *M. javanica* and *M. arenaria* races 1 and 2 in the greenhouse for the S1 through S7 generations. The three inbreds NC-44, NC-45, and NC-46 were the best lines selected in those progenies, and will be released as 'Manteo', 'Shelby', and 'Lucia', respectively (named for towns in North Carolina).

Description

'Lucia', 'Manteo', and 'Shelby' are pickling cucumber inbreds with good horticultural traits as well as resistance to several root-knot nematodes (Table 1). Gall indices for *M. javanica* and *M. arenaria* races 1 and 2 were

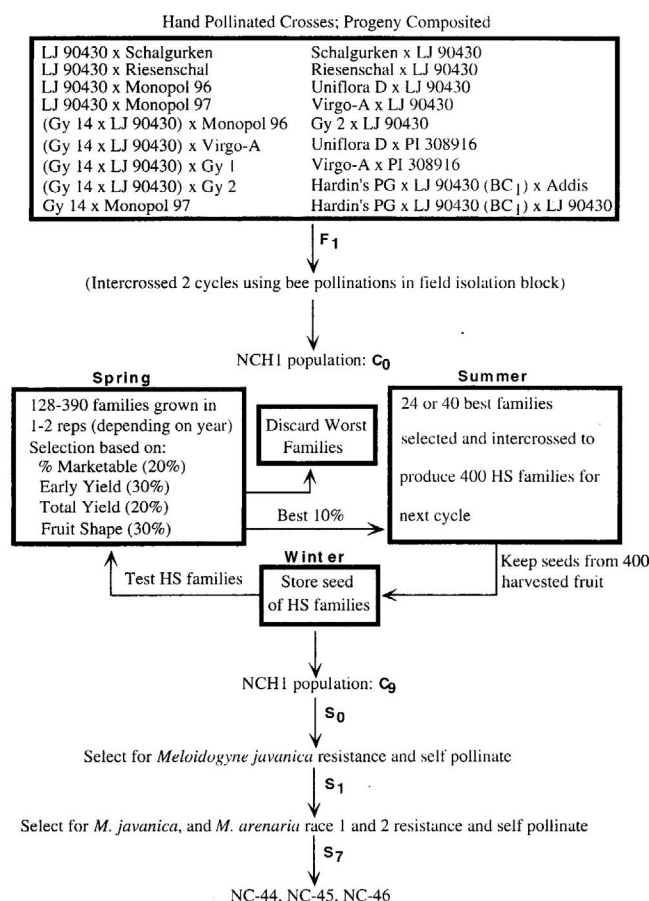


Fig. 1. Pedigree for the development of 'Manteo' (NC-44), 'Shelby' (NC-45), 'Lucia' (NC-46) nematode-resistant cucumber inbred lines.

Table 1. Comparison of 'Lucia', 'Manteo', and 'Shelby' cucumber inbreds with 'Sumter' for resistance to root-knot nematodes (*Meloidogyne arenaria* races 1 and 2 and *M. javanica*).^a

Cultivar	<i>M. arenaria</i> race 1		<i>M. arenaria</i> race 2		<i>M. javanica</i>	
	Gi	Rf	Gi	Rf	Gi	Rf
Lucia	12	0	11	0	10	0
Manteo	9	0	13	0	6	0
Shelby	9	0	9	0	10	0
Sumter	47	3	53	6	75	479
LSD ($P \leq 0.05$)	7	1	7	3	10	255

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^aPlants were rated for resistance using the gall index system (Gi = 0% to 100 % of roots galled) 10 weeks after planting (Barker et al., 1986). Rf (Reproduction factor) = (Final nematode density)/(Initial nematode density) (Oostenbrink, 1966) and calculated as final number of eggs in the roots/5000.

significantly lower on the three inbreds than on 'Sumter', and there was no reproduction on the three inbreds (Table 1).

'Lucia', 'Manteo', and 'Shelby' are indeterminate and monoecious, with medium-green colored vines. Plants flower ≈ 30 to 40 d after planting under North Carolina field conditions (Tables 2 and 3). Flowering is sequential, beginning at the first node. Multiple pistillate flowers are produced at some nodes. Fruits are pickling type, dark-green, with medium-sized warts, and white spines. The fruit length :

diameter ratio is short ('Shelby', 3.0), medium ('Manteo', 3.4), or long ('Lucia', 3.9) depending on cultivar (Fig. 2).

Yield and quality traits of 'Lucia', 'Manteo', and 'Shelby' were evaluated over 2 years in stage 1 trials, and 1 year in stage 3 and 4 trials at North Carolina State Univ. Yields of the three inbreds were similar to 'Calypso' and greater than 'Sumter' (Tables 2, 3, and 4). However, 'Calypso' and 'Sumter' had better fruit quality traits than did the inbreds.

Several disease resistances have been evalu-

ated for the three inbreds (Table 5). 'Manteo' is more susceptible to powdery mildew [*Sphaerotheca fuliginea* (Schlecht.: Fr.) Poll.] than 'Shelby' or 'Lucia', based on greenhouse and field data (Tables 2 and 5). Under greenhouse conditions, 'Manteo' developed powdery mildew on the stems and petioles, but not the leaf blades (indicating moderate resistance); 'Shelby' and 'Lucia' had no symptoms on the stems (indicating high resistance). 'Manteo' was susceptible to scab (*Cladosporium cucumerinum* Ell. & Arth.), while

Table 2. Comparison of 'Lucia', 'Manteo', and 'Shelby' (root-knot nematode-resistant cucumber inbreds) with standard pickling cultivars for yield and other quality traits.²

Cultivar	Fruit no. per plot		Fruits per plant	Days to flower ^y	Fruit quality rating ^x	Fruit firmness (N) ^w	L : D ratio ^v	Anth. rating ^u	PM rating ^u
	Total	Marketable							
Lucia	38	27	3.3	43	5.5	62	3.9	6	0
Manteo	26	17	1.8	40	5.8	71	3.4	7	5
Shelby	31	23	1.7	43	4.8	80	3.0	7	0
Calypso	33	24	1.4	42	5.7	76	2.9	6	1
Sumter	21	17	1.0	42	7.5	80	3.2	5	0
Wis. SMR 18	11	4	0.7	43	3.7	67	2.8	6	3
LSD ($P \leq 0.05$)	NS	21	2.3	3	1.5	13	0.6	NS	2
Mean	40	31	2.4	42	5.9	71	3.1	4	1
CV (%)	34	34	46.6	3	12.6	49	9.9	28	84

²Cultivars from Spring 1995 stage 1 pickling cucumber trial of 37 cultigens. Data (means of two replications and two harvests) are based on the analysis of 37 cultigens.

^yDays to first flowering of 50% of the plants in a plot.

^xQuality rating: 1-3 = poor, 4-6 = intermediate, 7-9 = excellent.

^wFirmness measured in Newtons on three grade no. 3 fruits using a punch tester (8-mm-diameter tip).

^vL : D is the length to diameter ratio based on five grade no. 2 fruits.

^uDisease rating: 0 = none, 1-2 = trace, 3-4 = slight, 5-6 = moderate, 7-8 = advanced, 9 = plant dead. Anth. = Anthracnose caused by *Colletotrichum orbiculare*, and PM = powdery mildew caused by *Sphaerotheca fuliginea*.

Table 3. Comparison of fruit yield and quality traits of standard pickling cultivars vs. those of 'Lucia', 'Manteo', and 'Shelby' (root-knot nematode-resistant cucumber cultivars) and hybrids of those inbreds crossed with Gy 2, Gy 4, Gy 5, and Gy 14.²

Cultigen	Fruit no. per plot		Fruits per plant	Days to flower ^y	Gyn. rating ^x	Fruit quality rating ^w	Fruit firm. (N) ^v	L : D ratio ^u	Anth. rating ^t
	Total	Marketable							
Inbreds									
Lucia	18	16	1.3	31	3	5.2	80	3.5	4
Manteo	14	9	1.1	31	5	5.0	76	3.0	8
Shelby	12	10	0.9	33	4	5.7	76	2.7	4
Gy 2	20	17	1.3	29	8	5.7	80	2.2	3
Gy 4	20	19	2.0	29	9	5.5	85	2.2	2
Gy 5	9	7	1.8	30	9	4.3	76	2.6	---
Gy 14	7	7	2.6	36	9	5.8	85	2.7	3
Sumter	6	6	0.8	34	4	6.5	71	2.9	3
Wis. SMR 18	3	3	0.4	34	3	3.8	80	2.8	6
Hybrids									
Gy 2 × Lucia	19	18	1.3	29	6	6.2	76	3.2	5
Gy 2 × Manteo	08	05	1.5	34	8	5.0	89	3.3	5
Gy 2 × Shelby	22	20	1.6	30	4	6.2	76	3.3	6
Gy 4 × Lucia	12	12	1.0	32	3	5.7	80	3.5	4
Gy 4 × Manteo	13	10	1.4	32	6	6.0	80	3.2	6
Gy 4 × Shelby	13	13	0.9	30	4	7.3	85	3.0	5
Gy 5 × Lucia	12	08	1.4	33	4	6.2	80	3.4	3
Gy 5 × Manteo	08	07	2.0	31	6	6.0	76	3.0	5
Gy 5 × Shelby	05	05	1.3	36	4	6.3	76	3.5	2
Gy 14 × Lucia	21	18	1.4	31	5	5.5	80	3.5	5
Gy 14 × Manteo	13	09	1.3	29	8	5.8	71	2.7	7
Gy 14 × Shelby	14	11	1.4	33	6	4.8	76	1.9	3
Calypso	11	09	1.1	32	8	6.5	71	2.6	5
LSD (<i>P</i> ≤ 0.05)	15	13	1.1	4	2	1.6	9	0.4	2
Mean	14	12	1.4	31	5	6.0	76	2.9	4
cv (%)	50	53	39.0	0.6	18	13.0	31	7.0	32

²Data from stage 1 pickle trials, with two replications and two harvests.

^yDays to first flowering of 50% of the plants in a plot.

^xGynoeceous rating: 1 = androeceous, 2-3 = andromonoecious, 4-6 = monoecious, 7-8 = predominately gynoeceous, 9 = gynoeceous.

^wQuality rating: 1-3 = poor, 4-6 = intermediate, 7-9 = excellent.

^vFirmness measured in Newtons on three grade no. 3 fruits using a punch tester (8-mm diameter tip).

^uL : D is the length to diameter ratio based on five grade no. 2 fruits.

^tAnthracnose rating: 0 = none, 1-2 = trace, 3-4 = slight, 5-6 = moderate, 7-8 = advanced, 9 = plant dead.

'Shelby' and 'Lucia' were resistant (Table 5). All inbreds were susceptible to angular leafspot [*Pseudomonas syringae* pv. *lachrymans* Smith and Bryan (Young et al.)]. Based on greenhouse tests, 'Lucia' was resistant to anthracnose, caused by *Colletotrichum orbiculare* (Berk. & Mont.) von Arx. race 1, whereas 'Manteo' and 'Shelby' were susceptible. Field tests were variable (Tables 2, 3,

and 4), but the 1996 stage 1 pickling cucumber trial showed that 'Shelby' and 'Lucia' have moderate resistance to anthracnose.

The three cultivars are intended for use in breeding programs for the development of elite cultivars, and also directly in areas where *M. arenaria* and *M. javanica* nematodes are a problem. In order to test combining ability for fruit yield and quality, hybrids were made

using four elite, gynoeious inbreds (Gy 2, Gy 4, Gy 5, and Gy 14) as female parents and 'Lucia', 'Manteo', and 'Shelby' as male parents. The hybrids had no nematode resistance, but demonstrated the value of the three cultivars for other horticultural traits. All hybrids made with 'Lucia' had fruits with necks. Hybrids with 'Manteo' and 'Shelby' performed well for most traits (Tables 3 and 4). Hybrids of Gy 14 with 'Manteo' and 'Shelby' had yield and quality characteristics similar to those of 'Calypso' (Table 4). 'Lucia', 'Manteo', and 'Shelby' inbreds had similar yields in a multiple-harvest system (Table 4). However, 'Shelby' is probably the best inbred for consistent yield. 'Lucia' is a long-fruited inbred (length : diameter ratio of 3.4 to 3.9) and would be useful for fresh-market production, or in the development of root-knot nematode-resistant slicing cucumbers.

Availability

Small amounts of breeder's seed are available from T.C.W.

Literature Cited

- Barker, K.R., J.L. Townshend, G.W. Bird, I.J. Thomason, and D.W. Dickson. 1986. Determining nematode population responses to control agents, p. 283-287. In: K.D. Hickey (ed.), *Methods for developing pesticides for control of plant pathogens*. APS Press, St. Paul.
- Oostenbrink, M. 1966. Major characteristics of the relation between nematodes and plants. *Mede. Landbouwhogeschool Wageningen* 66:1-46.
- St. Amand, P.C. and T.C. Wehner. 1991. Crop loss to 14 diseases in cucumber in North Carolina for 1983 to 1988. *Cucurbit Genet. Coop. Rpt.* 14:15-17.
- Walters, S.A. 1997. Resistance of cucumber to root-knot nematodes. PhD Diss. North Carolina State Univ., Raleigh.
- Walters, S.A., T.C. Wehner, and K.R. Barker. 1993. Root-knot nematode resistance in cucumber and horned cucumber. *HortScience* 28:151-154.
- Walters, S.A., T.C. Wehner, and K.R. Barker. 1995. A split root technique for multiple nematode resistance in cucumber. *Cucurbit Genet. Coop. Rpt.* 18:29-30.

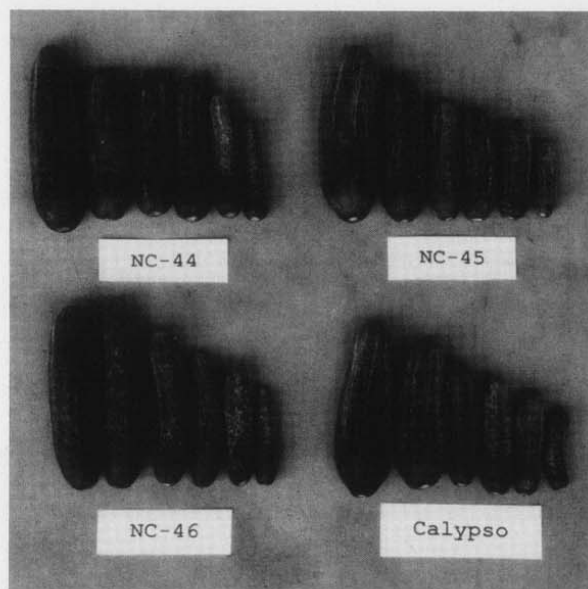


Fig. 2. Fruits of 'Manteo' (NC-44), 'Shelby' (NC-45), 'Lucia' (NC-46), and 'Calypso'.

Table 5. Resistance of 'Lucia', 'Manteo', and 'Shelby' cucumber inbreds to important diseases in greenhouse tests.^z

Cultigen	Disease ^y				
	Scab	Anth	ALS	PM	
Lucia	HR	HR	S	MR	
Manteo	S	S	S	S	
Shelby	HR	S	S	MR	
WI 2757	HR	HR	HR	HR	
Coolgreen	S	S	S	S	

^zS = susceptible, MR = moderately resistant, and HR = highly resistant.

^yScab = scab caused by *Cladosporium cucumerinum*, Anth = anthracnose caused by *Colletotrichum orbiculare* race 1, ALS = angular leafspot caused by *Pseudomonas syringae* pv. *lachrymans*, PM = powdery mildew caused by *Sphaerotheca fuliginea*.

Table 4. Comparison of fruit yield and quality of root-knot nematode-resistant cucumber inbreds ('Lucia', 'Manteo', and 'Shelby') vs. those of their hybrids and standards.^z

Cultigen	Fruit mass (Mg-ha ⁻¹)		Fruit value ^y (\$/ha)		Quality ^x rating		Firmness ^w (N)		L : D ^v ratio		Balloon ^u bloater (%)	Anth. ^t rating
	Sp	Sm	Sp	Sm	Sp	Sm	Sp	Sm	Sp	Sm		
Lucia	71	122	356	428	5.7	5.6	65.4	69.8	4.0	3.4	5	6
Manteo	121	48	662	152	5.3	5.1	74.3	68.1	3.7	3.3	0	7
Shelby	106	143	531	688	5.3	4.9	80.1	74.3	3.3	3.0	0	7
Gy14 × Lucia	95	207	458	765	6.4	5.7	71.2	66.7	3.3	3.0	0	8
Gy14 × Manteo	151	179	775	693	5.9	5.6	75.6	71.2	3.2	3.0	3	6
Gy14 × Shelby	214	194	1076	745	6.3	5.4	72.5	62.3	3.1	3.0	0	8
Calypso	134	164	841	656	6.3	5.7	81.4	69.8	3.2	3.0	0	6
Wis. SMR 18	81	43	447	139	4.3	4.4	74.3	66.7	3.2	2.8	0	8
LSD ($P \leq 0.05$)	105	100	535	449	0.9	1.2	11.6	9.8	0.4	0.4	4	2
Mean	164	162	992	755	6.1	5.8	75.6	67.6	3.3	3.0	2	6
cv (%)	39	38	33	36	9.4	12.8	42.3	36.9	7.4	8.2	160	26

^zData from stage 3 and 4 pickle trials, with three replications and six harvests; Sp = spring; Sm = summer season.

^yValue = (Mg no. 1 × \$320) + (Mg no. 2 × \$160) + (Mg no. 3 × \$96).

^xQuality rating: 1-3 = poor, 4-6 = intermediate, 7-9 = excellent.

^wFirmness measured in Newtons on three grade no. 3 fruits using a punch tester (8-mm diameter tip).

^vL : D is the length-to-diameter ratio based on three grade no. 3 fruits.

^uPercent balloon bloaters rated for spring pickle trial only. Data are means for five fruits from each of two harvests.

^tAnthracnose rating (in summer only): 0 = none, 1-2 = trace, 3-4 = slight, 5-6 = moderate, 7-8 = advanced, 9 = plant dead.